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Hydrogeomorphic approach to assessing wetland functions developed under Corps' research program

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Scientists at the U.S. Army Engineer Waterways Experiment Station are developing a procedure for assessing the functions of wetlands under the Wetlands Research Program. The procedure is intended primarily for U.S. Army Corps of Engineers use and measures the ability of wetlands to perform specific functions. The procedure supports the Corps' Regulatory Program mandated by Section 404 of the Clean Water Act and can be used

- to compare project alternatives
- to compare pre and post project conditions for determining impacts or mitigation success
- to provide guidance for avoiding and minimizing project impacts, and
- to determine mitigation requirements.

The modular and hierarchical format of the procedure will make it easily adaptable to a variety of planning, management, educational, and other regulatory situations that involve the assessment of wetland function.

Wetland functions introduced

Wetland *functions* are the actions that are naturally performed by wetland ecosystems, or simply, the things that wetlands do. Wetland functions are a result of the interaction between the structural components of wetlands—such as soil, detritus, plants, and animals—and the physical, chemical, and biological processes that occur in wetlands. A *process* is a sequence of steps leading to a specific end. For example, the microbially mediated process of denitrification occurs in many wetlands and leads to the relatively simple wetland function of nitrogen removal (Fig. 1). More complex functions resulting from the interaction of structural components and multiple processes can also be identified. For example, the physical processes of overbank flooding, reduction of water velocity, and the settling of suspended particulates interact with physical structures and result in the wetland function of particulate retention.

Hydrogeomorphic classification introduced

Wetland ecosystems in the United States occur under a wide range of climatic, geologic, geomorphic, and hydrologic conditions. This diversity of conditions makes the task of assessing wetland functions difficult, because not all wetlands perform functions in the same manner, or to the same degree, if at all. Therefore, to simplify the assessment process, it is useful to classify wetlands into groups that function similarly. Classification narrows the focus of attention (1) to the functions a particular type of wetland is most likely to perform, and (2) to the characteristics of the ecosystem and landscape that control these functions. The benefits

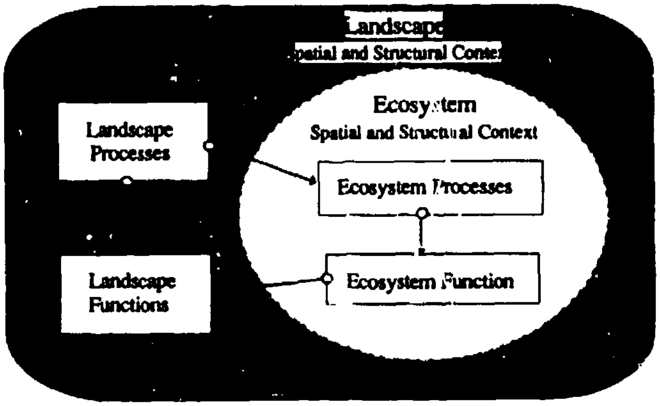

Figure 1. Relationship between wetland ecosystem structure, process, and function and landscape structure, process, and function.

of classification are a faster and more accurate assessment procedure.

The assessment procedure under development uses a hydrogeomorphic classification* to group wetlands on the basis of three fundamental characteristics: geomorphic setting, water source, and hydrodynamics. At the highest level of the classification, wetlands fall into one of five basic hydrogeomorphic classes including: depression, slope-flat, riverine, fringe, and extensive peatland.

The classification can be applied at a regional level to narrow the focus even further. The regions identified by Omernik (1987), Bailey (1994), or Bailey et al. (1994) and based on climatic, geologic, physiographic, and other criteria, provide a convenient starting point for applying the classification Within a region, any number of *regional hydrogeomorphic wetland subclasses* can be identified based on landscape scale factors such as geomorphic setting, water source, soil type, and vegetation. The number of regional subclasses identified depends on the diversity of condition in a region and assessment objectives. Experience shows that regional subclasses provide a scale at which assessment efficiency and accuracy can be maximized in the context of the Corps' 404 Regulatory Program.

Assessment procedure introduced

The assessment procedure is unique in that it utilizes the concepts of hydrogeomorphic classification, functional capacity, reference domain, and reference wetlands. These can be understood in the context of the three phases of the procedure which include: characterization, assessment, and application.

The characterization phase includes the following steps:

- Definition of assessment objectives
- Characterization of the proposed project, the wetland ecosystem, and landscape context
- Screening for "red flag" features, and
- Identifying wetland assessment area(s) within the project area on the basis of hydrogeomorphic classification, physical separation, and potential project impacts.

The assessment phase of the procedure provides a measure of the ability of a wetland to perform functions. Wetland functions are measured in terms of *functional capacity*. The concept of functional capacity is based on two assumptions. First, the inherent capacity of a wetland to perform a function is dictated by the structural components, and the physical, chemical, and biological processes of the wetland. Second, the functional capacity of a wetland (the level at which a function is actually performed), is determined, to a greater or lesser degree depending on the function under consideration, by interactions between the wetland and the surrounding environment.

An analogy to explain functional capacity

An analogy is useful to explain the concept of functional capacity. Consider a water pump and its function of moving water. Assume the water pump is designed to move 100 gpm, and its inherent capacity is 100 gpm. However, the functional capacity of the water pump—or the rate at which it actually moves water—depends not only on its inherent capacity to move water, but also the context in which the water pump occurs. If the water pump is attached to a hose that delivers 100 gpm, the functional capacity of the water pump is 100 gpm, the same as its inherent capacity. However, if the water pump is attached to a hose that is capable of delivering only 50 gpm, the functional capacity of the water pump is 50 gpm, though its inherent capacity is still 100 gpm. Like most analogies, this one is oversimplified and imperfect. While the inherent capacity of a water pump is static, the inherent capacity of an ecosystems is dynamic, and can change over time. For example, the inherent

* The assessment procedure has been dubbed the "Hydrogeomorphic Approach" because it uses the hydrogeomorphic classification of wetlands. (Brinson, M. M. 1993. A Hydrogeomorphic Classification for Wetlands. Wetlands Research Program TR-WRP-DE-4. US Army Engineer Waterways Experiment Station, Vicksburg, MS.)

capacity of a wetland to provide habitat may change as plant succession takes place.

The concepts of inherent and functional capacity can be applied to wetland ecosystems and the functions they perform. For example, consider the floodwater storage function performed by some wetlands (Fig 2.). The inherent capacity of a riverine wetland to store overbank floodwater depends on characteristics of the wetland's storage capacity by volume to store floodwater (how big is the bucket?). However, the functional capacity, or actual amount of floodwater stored in the wetland depends on the ability of the watershed to generate overbank floods. This ability is dictated by watershed characteristics such as the size of the watershed, the intensity and duration of precipitation in the region, runoff coefficients of the watershed, and the location of control points in the stream above and below the wetland. A wetland with a potential inherent capacity to store 100,000 gallons, based on peak flood elevation during the average annual peak flood, could have an actual functional capacity ranging from 100,000 to 0 gallons depending on the conditions in the watershed of that wetland.

Figure 2. Bryophytes on tupelo trees indicate average annual depth of flooding in an Arkansas wetland

Functional capacity index introduced

The functional capacity of a wetland is determined using a *functional capacity index* (FCI). An FCI is a ratio of the functional capacity of a wetland under an existing, or predicted, condition, and the functional capacity of a wetland under attainable conditions. *Attainable conditions* are by definition the conditions under which the highest, sustainable level of functional capacity is attained across the suite of functions that wetlands in a *reference domain* naturally perform. The *reference domain* is simply the group of wetlands for which a functional capacity index is developed. The reference domain will normally be a regional hydrogeomorphic subclass. However, depending on assessment objectives, it could be composed of a larger or smaller number of subclasses and geographic extent. For example, if the assessment objective is to compare a subclass of wetlands in the watershed, the reference domain would include all wetlands in the subclass in the watershed.

Attainable condition, or the highest, sustainable level of functional capacity is presumed to occur in wetland ecosystems and landscapes that have not been subject to anthropogenic disturbance with long term effects. When undisturbed wetlands and landscapes do not exist or cannot be reconstructed from historical data, attainable condition is presumed to exist in the wetland ecosystems and environments that have been subject to the least amount of anthropogenic disturbance.

Functional capacity indices are based on an *assessment model* that defines the relationship between the ecosystem and landscape scale variables and functional capacity. The condition of a variable is measured directly, or indirectly using *indicators* (observable characteristics that correspond to specific variable conditions). Variables are assigned an index, ranging from 0.0 - 1.0, based on the relationship between variable condition and functional capacity in the reference domain. This relationship is established using *reference wetlands*. A reference wetland set is a group of wetlands that represent the range of conditions that exist in wetland ecosystems and their landscapes in the reference domain. The range of conditions represented include those resulting from natural processes (succession, channel migration, erosion and sedimentation) and anthropogenic disturbance.

Reference wetlands and their environments serve as the basis for scaling and calibrating variables in assessment models. The relationship between variable condition and functional capacity in the reference domain is established using either empirical data, expert opinion, best professional judgment, or combinations of these options. The relationship is formalized by using logical rules or equations to derive an FCI ranging from 0.0 - 1.0. An FCI of 1.0 corresponds to the level of functional capacity that exists under attainable conditions for the reference domain. An FCI of 0.0 reflects the absence of functional capacity.

Functional capacity units introduced

The FCI provides a measure of the ability of a wetland to perform a function relative to similar wetlands in the region. Theoretically, the FCI represents an estimate of an absolute quantification of function on a per unit area and time basis. For

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example, an FCI of 1.0 for the flood storage function represents the absolute number of cubic feet of water that are stored, in a specified wetland area over a specified period of time, under attainable conditions in the reference domain. The actual number cubic feet of water, with estimates of uncertainty, could be determined empirically for the same specified area of wetland and the same specified period of time.

In the 404 Regulatory Program, the primary application of an FCI is to compare different wetland areas such as project alternatives, or pre/post condition. However, comparing two wetland areas on the basis of an FCI alone can lead to erroneous conclusions. For example, consider the following scenario. A new highway is being planned, and there are two alternative routes under consideration. The first route will impact 5 acres of wetland with an FCI of 0.8 for a particular wetland function. The second route will impact 25 acres of wetland, also with an FCI of 0.8 for the same function. In comparing the two alternatives based on functional capacity, it would be correct to say that on a per unit area basis there was no difference between the alternatives. However, when incorporating the size of each wetland area into the comparison, a conclusion of no difference would be erroneous. The comparison of the two alternatives based on the functional capacity index and size of wetland would lead to a more appropriate conclusion that the first alternative is the least damaging to the selected wetland function.

The FCIs resulting from the assessment phase can be applied in a variety of ways during the application phase using *functional capacity units (FCUs)*. FCUs provide a measure of the ability of a wetland area to perform a function, and are calculated by multiplying an FCI by the area of wetland the FCI represents. For example:

$$FCU = FCI \times \text{size of wetland area}$$

R. Daniel Smith is an ecologist with the Wetlands Research Team, Environmental Laboratory, at the U.S. Army Engineer Waterways Experiment Station. He received his B.S. degree in Ecology from California Polytechnic University, San Luis Obispo, and an M.S. in Plant Ecology from Western Illinois University in Macomb. His current work is to develop a method for assessing wetlands functions in the context of the Corps' Regulatory Program. He has conducted research in floodplain forests along the Cache River, AR, provides technical assistance to Corps District personnel on wetland issues, and conducts training on assessing wetlands functions. He is currently pursuing a PhD at Southern Illinois University-Carbondale.

where:

FCU = Functional capacity units for wetland area

FCI = Functional capacity index for wetland area

Once the functional capacity of a wetland area is expressed in terms of FCUs, a number of the comparison necessary in the 404 permit review process can be made. For example:

- Comparing the same wetland area at different points in time (e.g., pre/post project conditions).
- Comparing WAAs in the same hydrogeomorphic wetland class at the same point in time.
- Comparing WAAs in different hydrogeomorphic wetland classes at the same point in time.

Implementation of the assessment procedure

The assessment procedure described in this article will be published as a WRP technical report. A variety of assessment models are being developed for use with the assessment procedure and will be published in the form of guidebooks for each hydrogeomorphic class, and case studies of regional hydrogeomorphic subclasses. The guidebooks will:

- provide a general description of the hydrogeomorphic class
- identify and provide rationale for the functions wetlands in that class are likely to perform, and
- provide generic assessment models and functional capacity indices; discussion of variables, variable conditions, their relationship to functional capacity, and the scaling of variable and functional capacity indices, using reference wetlands. Case studies represent the application of the hydrogeomorphic approach to a regional subclass. Case studies scale assessment models and FCIs to the regional hydrogeomorphic subclass, using reference wetlands. Case studies are being conducted for a variety of regional hydrogeomorphic subclasses, and will provide a template for applying the hydrogeomorphic approach to additional regional subclasses.

More information is available from Dan Smith at (601) 634-2718.

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Field investigation focuses on impacts of climate on bottomland hardwood (BLH) seedlings

by Carolyn Kim, U.S. Army Engineer Waterways Experiment Station

Wetlands restoration is a complicated task, especially when dealing with bottomland hardwood (BLH) forest areas that have been converted to agricultural use. The restoration process becomes more complex because of the climatic and environmental differences between the two areas. Scientists have found that seedlings which naturally regenerate in a BLH forest may barely survive when planted in an open field. In order to determine what climatic and environmental factors contribute to the success or failure of seedling growth and survival, scientists from the U.S. Army Engineer Waterways Experiment Station, under the Wetlands Research Program, will be conducting field experiments in the Delta National Forest and an adjacent agricultural field that is to be restored to BLH. The study site (Fig. 1) is located in Sharkey County, near Anguilla, Miss., which is approximately 60 miles to the north of the Waterways Experiment Station. This Corps of Engineers' study is part of an interagency wetland restoration project. Major research studies are conducted in the area by the National Biological Survey, the U.S. Fish and Wildlife Service, and the Soil Conservation Service.

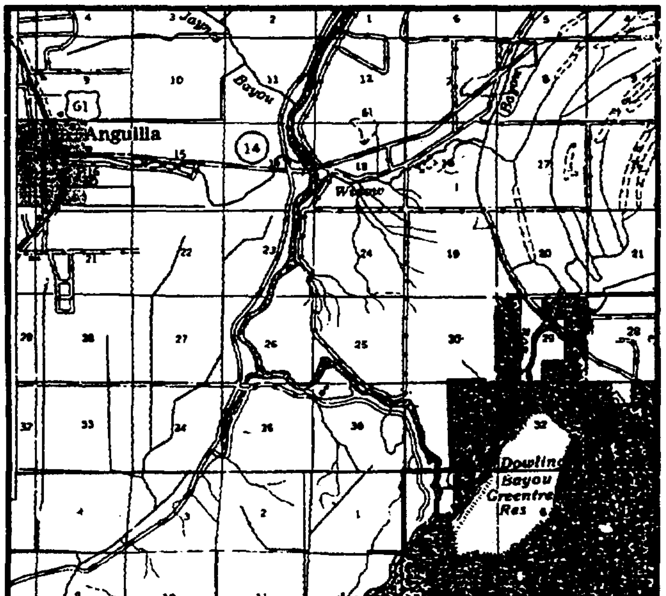

Figure 1. Site map of WRP study site, Delta National Forest, Miss.

Study objectives

The relationship between three factors will be studied:

- seedling growth rates,
- groundwater data, and
- weather station data.

The experimental design was developed by principal investigators Barbara A. Kleiss, ecologist, and Dr. Steven W. Sprecher, soil scientist. Analyzing meteorological, hydrological, and plant physiological data collected from the forest and the field will assist these scientists in making inferences about the climatic and environmental factors that contribute to variations in seedling survival and growth.

In addition to the principal investigators, several WES contract students are actively involved with the Sharkey County project. Contract students* Monica Craft, a biologist who recently received her Masters Degree from Alcorn State University, and Kimberly Seeley, a new graduate student at Louisiana State University, are actively conducting field work at the site. This field work included selecting the location for the weather stations, planting seedlings, installing groundwater wells, and setting up weather stations. With initial preparations completed, Craft and Seeley will be responsible for equipment maintenance and data collection during the next 12 months of the experiment.

Seedling survival and growth

Planting seedlings in the agricultural field will enable scientists to gather data about seedling physiology, morphology, and survival. These data will then be compared to climatic data. The seedling data collected will include stomatal conductance, leaf transpiration, and leaf water potential, as well as survival, growth rate, and height. The study calls for two BLH species, Nuttall oak (*Quercus nuttallii*) and water oak (*Quercus nigra*), in two stock types, container and direct-seeded

* Contract students attend post-secondary, degree-granting, educational institutions. These students are contracted by WES for temporary services to provide scientific or engineering work in support of research and development at the Department of Defense laboratories involved. WES employs approximately 300 contract students.

seedlings, to be planted in the open field. Field performance of these seedlings will be closely monitored throughout the growing season.

Groundwater wells

Groundwater wells will be used to record water levels over time in the forest and the field. Four wells were installed at each site at the following depths: 300 cm, 200 cm, 150 cm, and 50 cm.

Water levels have significant bearing on the outcome of the seedlings' growth and survival because soil saturation within the root zone can cause anaerobic conditions which stress the plants. The groundwater data collected in this investigation will be studied in conjunction with the data collected from seedlings and weather stations.

Weather stations

Two weather stations are used in the study: one located in the forest and one in the adjacent field. The weather stations were placed equidistant from the dividing line between the forest and the field in order to insure equally representative measurements, since the physical locations of the weather stations can affect the accuracy of data collected. Since unusual objects and environmental conditions in the immediate area of the instruments may distort rea..ngs, and thus making it impossible to obtain representative samples of the general area, the weather stations must be placed in areas that are ideally representative of the forest and field.

The weather stations' purpose is to collect meteorological and hydrological data. Instruments

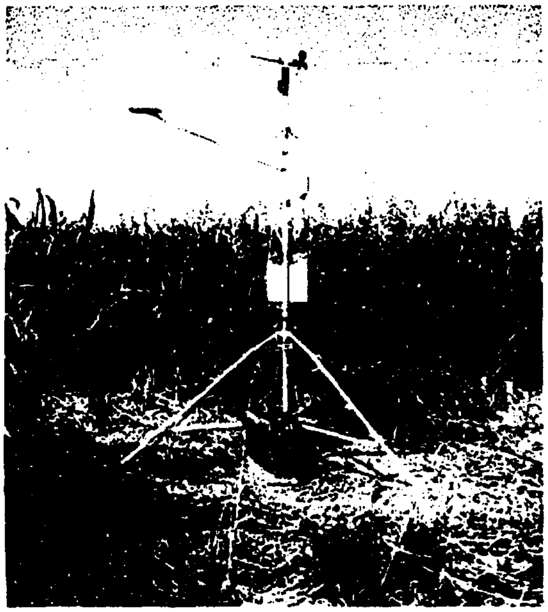

Figure 2. Weather station in open field

Carolyn Kim is a contract student in the Technology Transfer Office at the Wetlands Research and Technology Center, Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station. She was involved with the site preparations in the Sharkey County Weather Experiment. Kim is currently a student at the University of Texas at Austin.

gather data through sensors located on various parts of the weather station (Fig. 2). These sensors register soil moisture, soil temperature, precipitation, relative humidity, wind vectors, wind speed, air temperature, solar radiation, and barometric pressure. The data collected by these sensors are transferred to a data logger. A hand-held polycorder is brought to the test sites to download the meteorological and hydrological data for statistical analyses. The information will then be processed to identify trends in the climates for each environment. The meteorological and hydrological data from the weather stations will be analyzed in conjunction with data collected from the seedlings.

Data collection in the Sharkey County experiment is set to begin on Oct. 1, 1994 and will continue through Sept. 30, 1995, one water year. Once the experiment is underway, Seeley will check the weather stations every two weeks, and maintain the weather database. During these routine site visits, Seeley will download the data and test the sensors and loggers to make sure that they are still functioning properly.

Since a primary objective of this experiment is the tying of seedling physiology, morphology, and survival rate to meteorological data from the weather station and ground water wells, the seedlings and groundwater wells will also be checked every two weeks. Data about the seedlings' and groundwater wells' changes will then be recorded.

Wetlands Research Program scientists will analyze the collected data for evidence of the climatic and environmental factors that contribute to the success or failure of seedling establishment. Findings from the Sharkey County experiment should contribute to the successful completion of future wetlands restoration projects.

Additional information about the WRP project is available from Barb Kleiss at (601) 634-3836 or Steve Sprecher at (601) 634-3957.

Professional Meetings Announced

Environmental professionals call for papers

The National Association of Environmental Professionals has issued an invitation to submit abstracts for its 20th annual conference, scheduled for June 10-13, 1995, in Washington, D.C.

Topics of particular interest to wetland professionals include, among others,

- watershed management
- future land-use options
- GIS, databases & models in ecosystem management

Abstract submission deadline is October 28, 1994. Additional information is available from Shelley Cohen at (202) 966-1500.

Corps sponsored interagency workshop: New deadline for abstracts and reservation information announced

Wetland professionals may still submit abstracts for the Corps sponsored National Interagency Workshop on Wetlands until the new deadline on October 28, 1994. Abstracts must be 75 to 150 words long. Notice of acceptance and a format for the final paper will be mailed to the primary author by November 10, 1994. Final papers must be received by February 1, 1995, to be included in the workshop proceedings. Proceedings will be provided at registration.

Abstracts must be submitted to:

U.S. Army Engineer Waterways Experiment Station
Wetlands Research & Technology Center
ATTN: CEWES-EP-W
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
FAX: (601) 634-3664

The workshop will take place at the Clarion Hotel, 1500 Canal Street, in New Orleans. Rooms have been set aside for participants in the National Interagency Workshop on Wetlands at $66 per day for single and $78 per day for double occupancy. Reservations may be made by calling 1-800-824-3359 (outside of Louisiana) or 1-800-627-4500 (in Louisiana). Early reservation is recommended.

American Institute of Hydrology meeting to be held

The Society for Registered/Certified Hydrologists and Hydrogeologists announces their May 14-18, 1995 meeting *Water Resources at Risk*. The meeting will be held at the Red Lion Hotel in Denver. For more information the point of contact is the American Institute of Hydrology, Helen Klose, 3416 University Avenue S.E., Minneapolis, MN 55414, telephone (612) 379-1030, FAX (612) 379-0169.

Corps field notes

Education outreach support available with booklet

The Corps' reproducible, educational outreach booklet *The Young Scientist's Introduction to Wetlands* has recently been reprinted. Districts and Divisions are encouraged to request bulk mailings of the booklet. Requests are handled on a first come, first served basis, not to exceed 600 copies.

Requests from the private sector for use of the booklet in outreach activities may be referred to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, stock number 008-022-00296-1. Price per copy is $1.50.

WRP releases video

A video on "Techniques for Restoring and Creating Marshes and Forested Wetlands" was recently distributed to Corps Districts and Divisions. The video is 37 minutes long, and includes sections on design criteria, engineering aspects, planting considerations, a case study on coastal marshes, a bottomland hardwood restoration case study, and bioengineering applications.

The video is also available from the U.S. Army Engineer Waterways Experiment Station Library on interlibrary loan service, (601) 634-2355 or from the Wetlands Research & Technology Center, FAX (601) 634-3664.

The *Wetlands Research Program* ***Bulletin***, the information exchange bulletin of the U.S. Army Corps of Engineers Wetlands Research Program, is published in accordance with Army Regulation 25-30 to provide information concerning the Corps' wetlands research and development. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes nor are they to be published without proper credit. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. Address communications to Elke Briuer, CEWES-EP-W, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

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